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External Affairs Approval　　　　　　Date

Comparative Analysis of Bracket Slot Dimensions

Evaluating Different Manufacturing Techniques

J S. A. DeMeo

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J S. A. DeMeo, Maj, USAF, DC
Tri-Service Orthodontic Residency Program
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10 July 2015

Learning to Care for Those in Harm's Way

Comparative Analysis of Bracket Slot Dimensions

Evaluating Different Manufacturing Techniques

A THESIS

Presented to the Faculty of

Uniform Services University of the Health Sciences

In Partial Fulfillment

Of the Requirements

For the Degree of

MASTER OF SCIENCE

By

J S. A. DeMeo, BS, DMD

San Antonio, TX

April 24, 2015

Comparative Analysis of Bracket Slot Dimensions Evaluating Different Manufacturing Techniques

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DEDICATION

This thesis is dedicated to my mother, Christine Katchmar. Without her love and support I could never have accomplished my dreams.

ABSTRACT

Purpose: To determine the accuracy of brackets fabricated by casting, metal injection molding, and computer numerically controlled (CNC) milling. **Methods**: Six types of 0.022” brackets were studied: Avex, Victory, Mini Master, Precision, Stratus, and Marquis. The height of the slot bottoms and slot tops, the angles of the slot corners, the slot tapers, and the R^2 of the walls were calculated. **Results**: The slot bottoms of the Avex, Mini Master, Precision, and Marquis were undersized by 5.7%. The Victory was undersized by 3.0% and the Stratus was oversized by 1.8%. The slot tops of the Avex, Victory, Mini Master, Precision, and Marquis were all undersized by 3.4%, 1.4%, 4.7%, 0.2%, and 2.9%, respectively. The Stratus was oversized by 3.4%. All brackets displayed acceptable rectangularity and linearity. **Conclusion**: Avex, Victory, and Mini Master brackets were manufactured by CNC milling and displayed higher dimensional accuracy than the Stratus, Precision, or Marquis brackets.

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I. BACKGROUND AND LITERATURE REVIEW

Aligning teeth to achieve health and esthetics has been a goal of scientists and clinicians for hundreds of years. The early pioneers in this field such as Fauchard and Harris used devices that tipped teeth into proper alignment yet had limited ability to control the roots (21, 26). This was unacceptable to the clinicians of the time, and they progressed through various enhancements and iterations of these devices, which ultimately culminated in the invention of the Edgewise appliance by Edward Angle in 1928 (21, 23, 24, 26). The Edgewise appliance was greatly accepted by the orthodontic community with the bracket itself being the most highly regarded aspect and was considered Angle's greatest achievement. For the first time, by aligning the slot of the bracket horizontally the Edgewise appliance allowed for both the crown and root movement to be controlled with a greater degree of precision than had been able to achieved before. This allowed correction of malocclusions both efficiently and effectively.

The development of the dimensions of the Edgewise bracket originated from work with precious metal wires, and Angle's arduous research showed that the best results were obtained by using a slot size of 0.022 inches (20). The design of the Angle bracket allowed for precise control of the tooth in the three orders of movement, including the most difficult, the third order — torque. Obtaining a satisfactory torque of the teeth was important for development of proper occlusion and an esthetic result (7). Angle achieved proper torque by introducing a couple with a rectangular wire within the orthodontic slot (11). The precision of the slot is critical to the success of orthodontic treatment, and Cecil

Steiner quickly realized that an improvement of the bracket could be made if it was strengthened by careful and accurate milling from a single solid piece of metal, and the slot held to very exact dimensions (26). The brackets must be precisely manufactured so that they are accurate up to 0.001 inches (21), and, according to ISO 270020:2010 (E), bracket measurements must be recorded to the nearest 0.00039 inches (0.01 mm).

At the beginning of the Industrial Revolution, American manufacturers attempted to break away from the Colonial influence by developing an "American standard" formulation that differed from the old British Imperial Standard, which lead to the standards in Europe. This led to a spectrum of slot sizes in brackets that ranged from 0.0178 to 0.0237 inches due a variety of factors, including differences in machine tooling between the United States, British, and European standards. This evolved into current times when different corporate criteria for tolerances in manufacturing, the realization that oversized brackets lead to more favorable sliding mechanics, and a lack of unified specification standards worldwide have continued to influence the manufacturing of brackets (9).

The development of the bracket continued into the 20th Century, and at this time the introduction of the 0.018 inch bracket that was found to be as efficient with stainless steel wires as the 0.022 inch bracket was with gold wires (20). This research promulgated a divide between practitioners, resulting in Europeans using the 0.018 inch bracket and Americans using the 0.022 inch bracket (9). This divide continues to the present with some practitioners currently advocating for a unification of both sizes into a one-size metric bracket (9, 20).

Unification would allow the practice of orthodontics to become more in line with the global scientific community and allow for more precise manufacturing of brackets.

Therefore, due to the enhancements to the Edgewise appliance the manufacturing process became more critical. The Edgewise appliance required many difficult bends in order to achieve an esthetic and functional occlusion. These bends are often time consuming for the clinician and can lead to significant error if done incorrectly. Therefore, numerous attempts were made by clinicians, such as Holdaway, Lee and Jaraback, to develop a simpler and more accurate appliance by altering the position of the brackets or milling torque into the face of the Edgewise bracket. However, it was not until Larry Andrews developed his Straight-wire appliance in the 1970s, based on his Six Keys of Normal Occlusion, that a completely pre-adjusted appliance came into use (24). This advance in the Edgewise appliance was received enthusiastically, but, due to the specifications of each individual bracket, it was impractical for milling of the brackets, and a precision casting method was developed to manufacture them (23). It is still thought by many that machine milling, even with the latest Computer Numerically Controlled (CNC) milling machines, is not accurate enough and that brackets should either be cast or metal injection molded for the most accurate result (21, 23). However, to correct for shrinkage errors in the casting process, some manufacturers then mill the slots into the brackets to achieve greater precision (21).

Metal Injection Molding (MIM) is a process that allows for very fine metal powders to be put into a mold and then sintered in a furnace, which allows for complex shapes to be manufactured with very good dimensional stability at a high production rate compared to traditional casting (8). MIM created brackets will tend to have rounder corners than precision grinding and machining techniques, which have significant impact on bracket slot dimensions and affect the finish of a case (14). McLaughlin advocates that MIM is less accurate and results in a bracket with varying angles and degrees of torque (16). He advocates that the modern CNC manufacturing process with the use of Computer Aided Design and Computer Aided Manufacturing (CAD-CAM) allows for more flexibility in design, which both increases bracket strength and creates more accurate slot dimensions (17). McLaughlin claims that these advancements will lead to "more precise control and more reliable movement of the teeth, which makes treatment faster and more predictable."

The goal of this current study was to evaluate the dimensional accuracy of brackets manufactured with different techniques such as casting, MIM, and CNC milling. To achieve this goal numerous methods to measure bracket dimensions using variety of techniques have been examined including precision gauges (3, 7), inference from torque measurement (19), electron microscopy (1), fluorescent stereo microscopy (5), atomic force microscopy (12), and, most commonly, optical microscopy (2, 11, 13, 14, 15, 18, 22). This study used optical microscopy since it provided the greatest accuracy combined with the greatest convenience allowing for brackets to be measured up to 0.1 microns (15).

II. OBJECTIVES

The purpose of this study was to evaluate the dimensional accuracy of brackets manufactured with different techniques such as casting, Metal Injection Molding, and Computer Numerically Controlled milling.

III. HYPOTHESIS

Hypothesis: There will be a significant difference in the accuracy of the slot dimensions among brackets manufactured by Computer Numerically Controlled milling and brackets manufactured by other methods.

Null Hypothesis: There will be no difference in the accuracy of the slot dimensions among the brackets manufactured by different techniques.

IV. MATERIALS AND METHODS

In this study six types of 0.022 inches (0.559 mm) slot upper right central incisor steel brackets were selected and analyzed:

1. Avex Suite (Opal, Jordan, UT)
2. Victory Series MBT (3M, Monrovia, CA)
3. Mini Master Series MBT (American, Sheboygan, WI)
4. Precision Series MBT (Elite Ortho Products, Boca Raton, FL)
5. Stratus MBT (Fairfield Ortho Products, Fairfield, CT)
6. Marquis MBT (Orthotechnology, Tampa, FL).

The investigation used a sample size of 30 for each of the six different bracket types.

Using a digital camera through an Axio Zoom.V16 stereo zoom fluorescent optical microscope (Carl Zeiss, MicroImaging GmbH, Jena, Germany) the mesial profiles of the brackets photographed (Figures 1-6). The brackets were mounted in a Reprosil Putty matrix (Dentsply Caulk, Milford, DE) to ensure reliable alignment during image capture. Brackets were carefully aligned so that the slots were imaged perpendicular to the slot. Alignment was confirmed by visually reviewing images to ensure that brackets were not tilted. The images were calibrated and processed using Zen Pro 2011 commercial software (Carl Zeiss, MicroImaging GmbH, Jena, Germany). Points were selected from the image outlining the bracket dimensions (Figure 7). Points were exported for analysis in a spreadsheet (Microsoft Office Excel 2010, Microsoft Corporation, Redmond, WA, USA).

In each image 15 points were selected: five along the incisal wall; five along the gingival wall; and five along the internal slot (bottom) wall (Figure 7). These points were then plotted on a two-dimensional Cartesian (x, y) coordinate system, and best-fit lines calculated. The two end points along each wall were selected first; the four points closest to each corner were selected just outside the radius of that corner. Using the y-coordinates from the two endpoints, the middle three points were selected to be evenly spaced. This process ensures that all five points along a given wall will be nearly equal distance.

In Excel, a best-fit line was generated for all of the walls using linear regression (Figure 8). A coefficient of determination (R^2 value) was calculated for each regression line. From these lines the slot height at the top and bottom, the slot taper, and slot rectangularity were calculated. The height of the slot bottom was calculated by taking the lowest point on the incisal wall and running a line parallel to the internal wall until it contacted the gingival wall (Figure 9). This calculation was repeated for the highest point on the incisal wall to determine the height of the slot top.

The angles of the slot corners (Θ_1, Θ_2) and slot taper (Θ_3) were calculated using the corresponding slopes of the incisal and gingival walls in relation to the slope of the internal wall (Figure 11).

The accuracy of the slot was assessed by the degree of deviation that each of the six brackets exhibited from the manufacturer's specification of 0.022 inches (0.559 mm), as well as, by the degree of variation within each of the six brackets. In addition, the accuracy of the rectangularity of the slots was assessed by comparing the angles of the walls to the nominal angle of 90°. Finally, the taper of the walls were assessed for uniformity; the coefficient of determination (R^2 value) gave a descriptive analysis of the linearity of each wall.

Figure 1: Bracket 1 (Avex Suite, Opal)

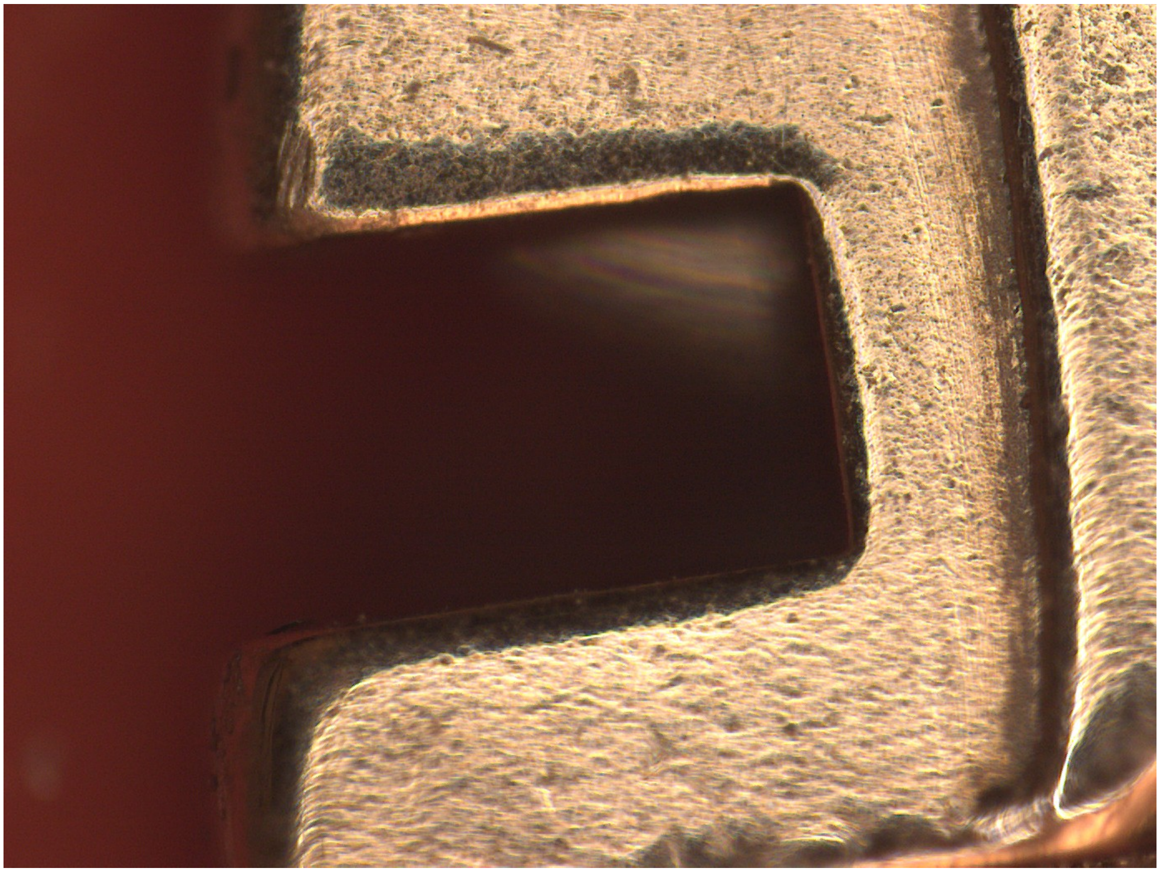


Figure 2: Bracket 2 (Victory Series, 3M)

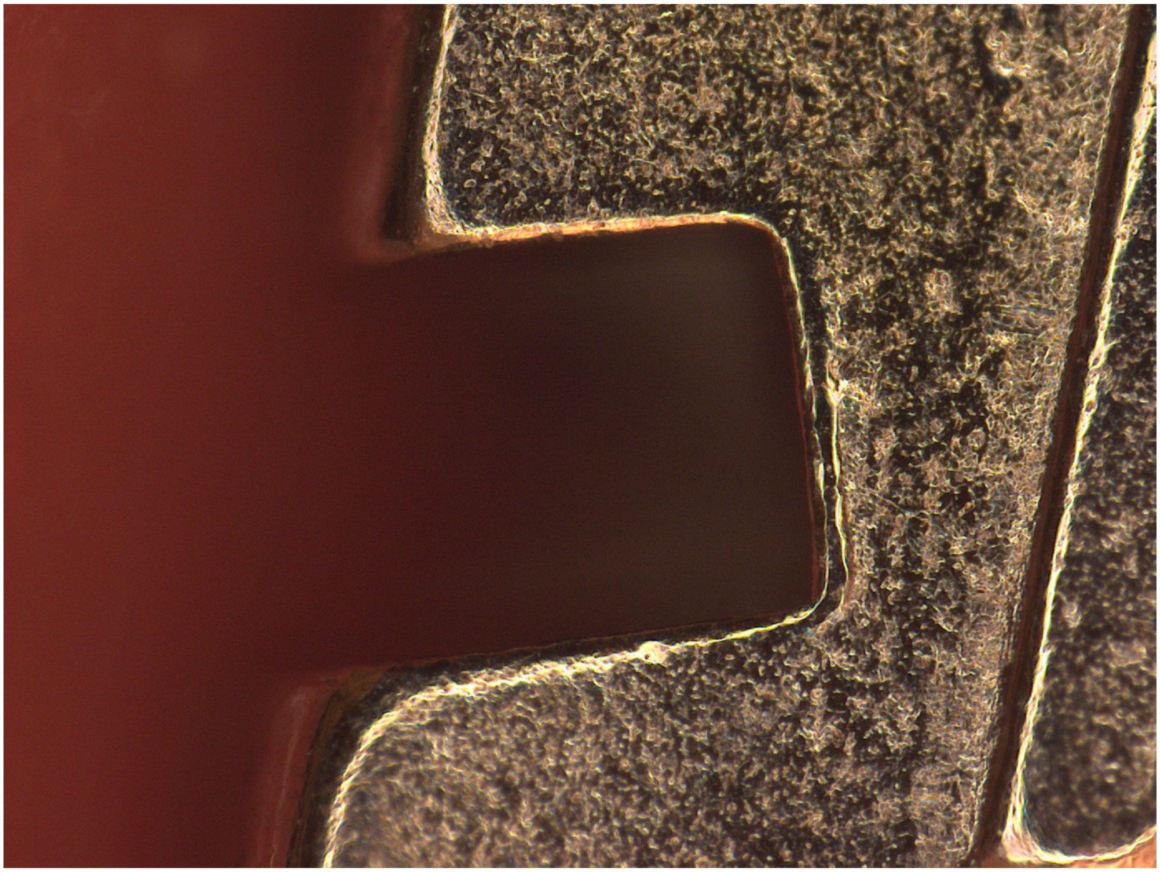


Figure 3: Bracket 3 (Mini Master Series, American)

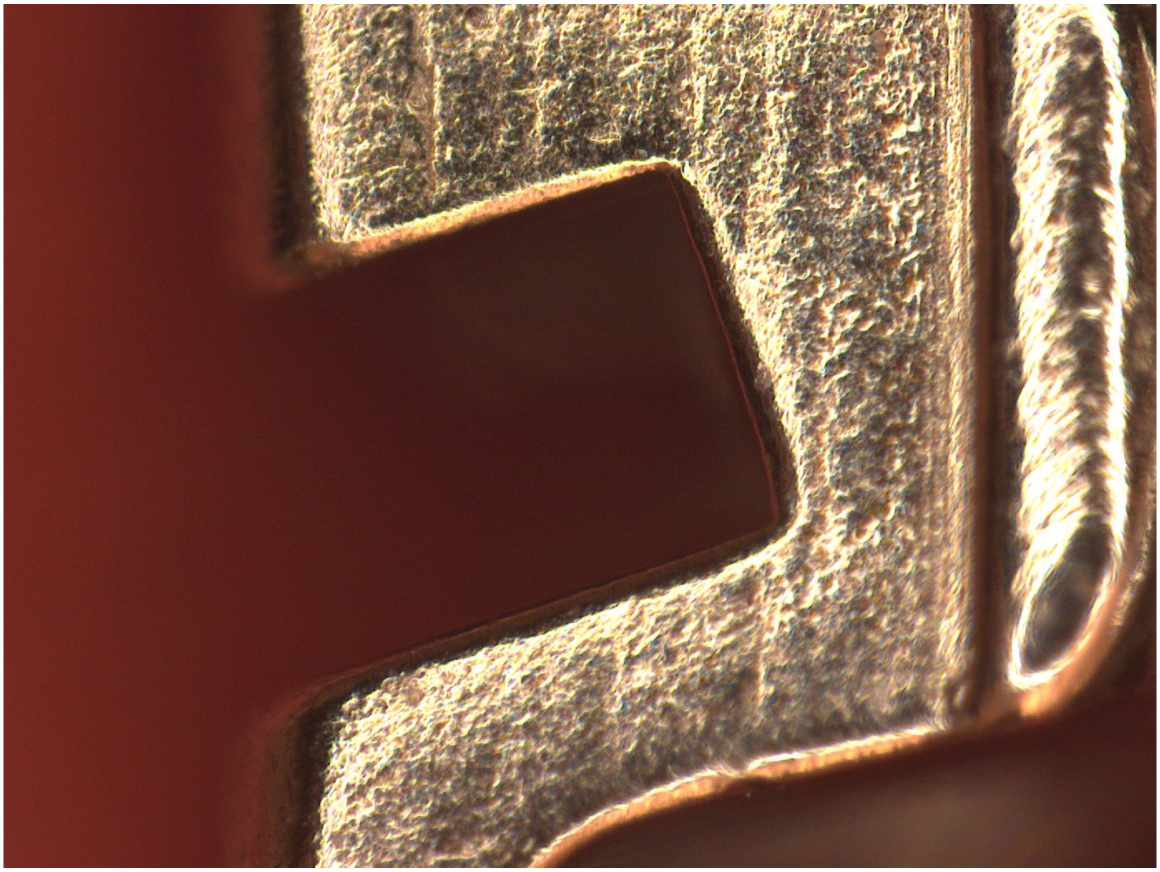


Figure 4: Bracket 4 (Precision Series, Elite Ortho Products)

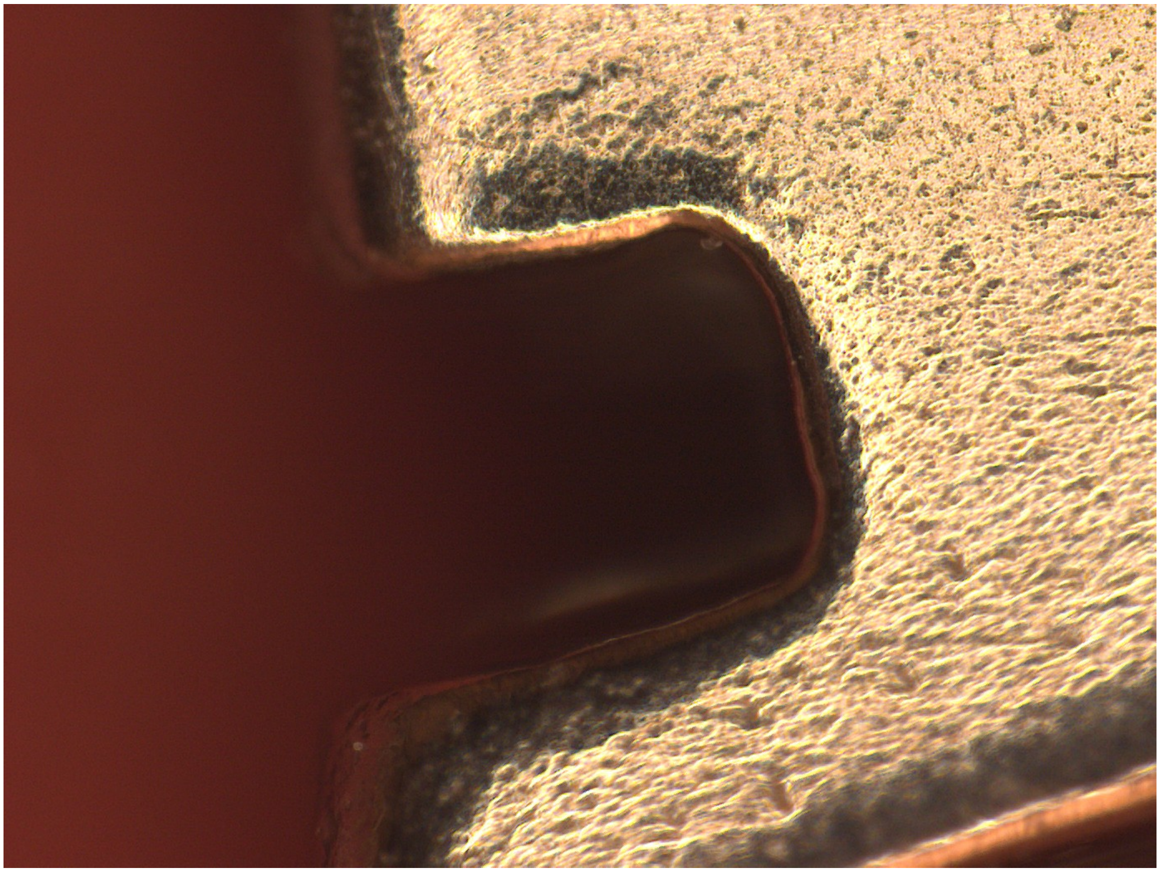


Figure 5: Bracket 5 (Marquis, Orthotechnology)

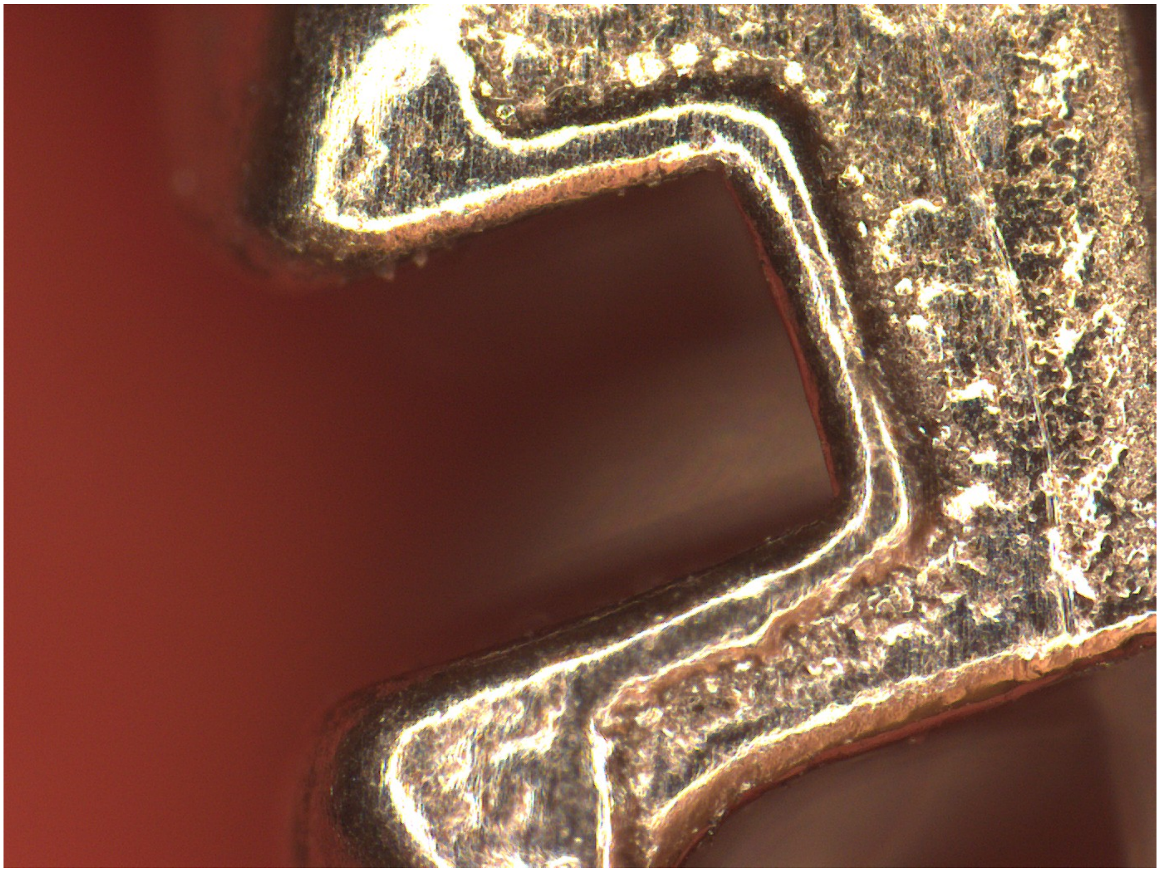


Figure 6: Bracket 6 (Stratus, Fairfield)

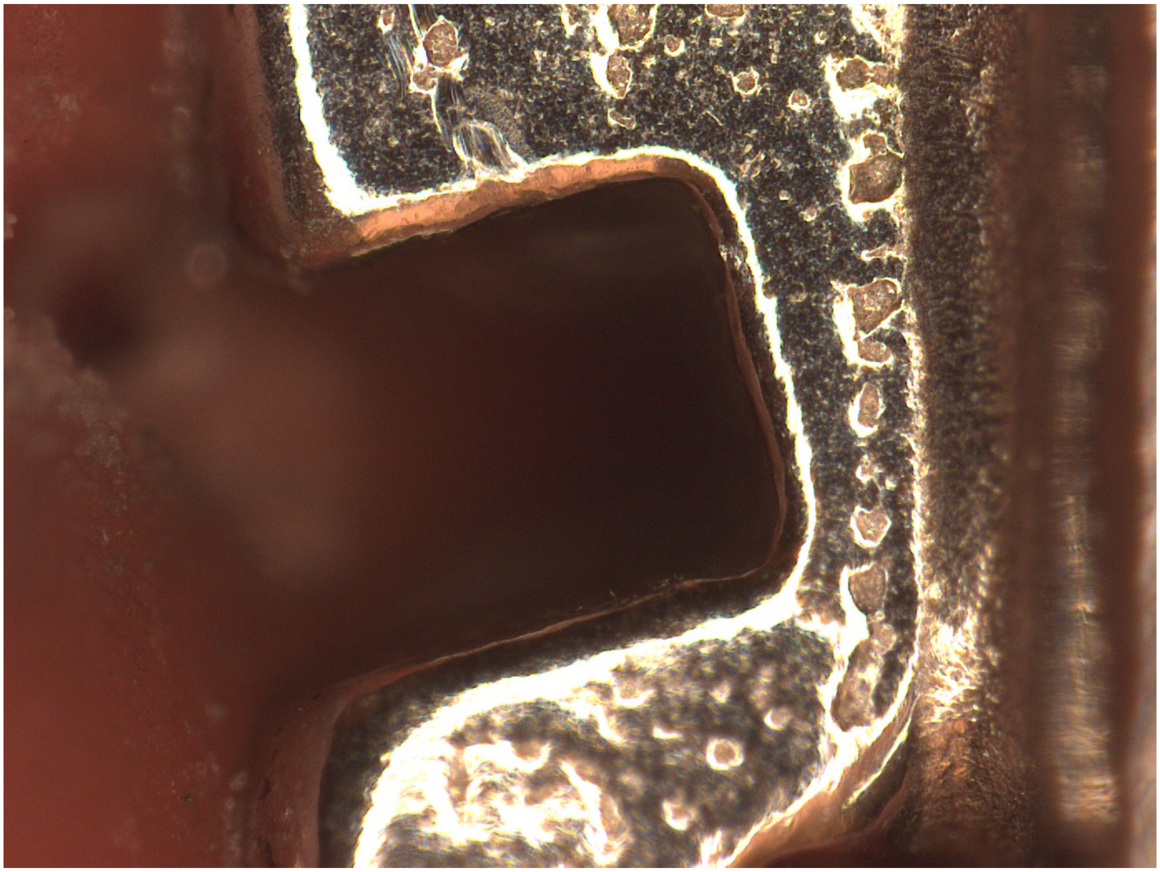


Figure 7: Example of points selected using Bracket 1 (Avex Suite, Opal)

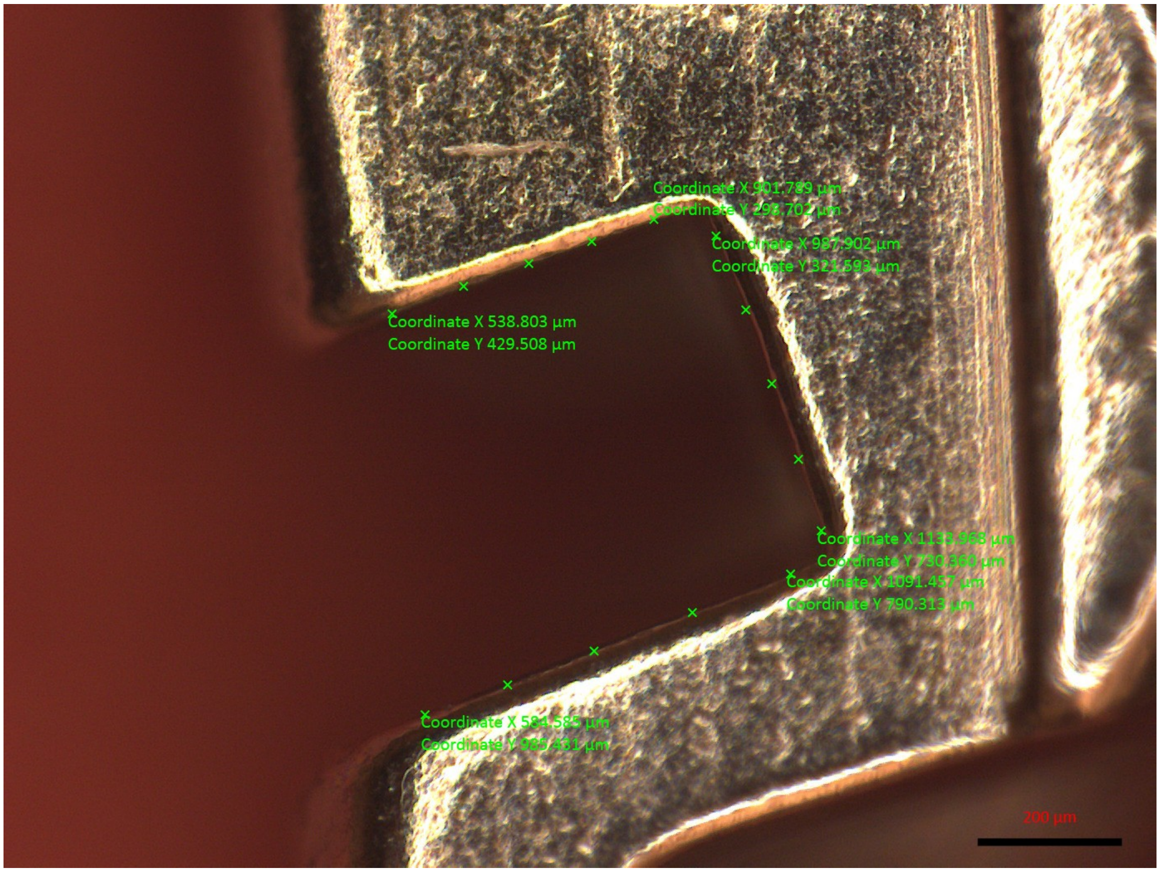


Figure 8: Example of points transferred to Excel, graphed, and regression lines calculated using bracket 1 (Avex Suite, Opal)

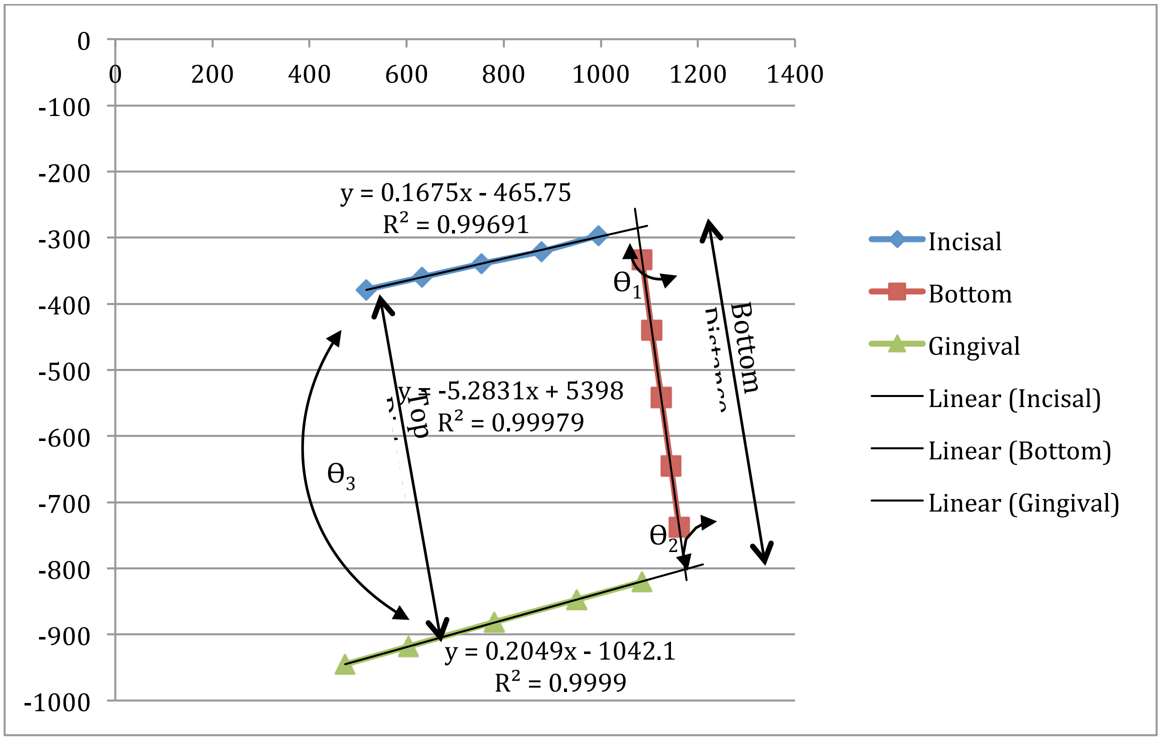


Figure 9: Formula for calculating distance between points on a Cartesian plane

$$distance = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Figure 10: Formulas for calculating angles (Θ_1, Θ_2, and Θ_3)

$$\Theta_1 = \arctan\left(\frac{1}{\text{slope}_{\text{bottom}}}\right) - \arctan\left(\frac{1}{\text{slope}_{\text{incisal}}}\right)$$

$$\Theta_2 = \arctan\left(\text{slope}_{\text{bottom}}\right) - \arctan\left(\text{slope}_{\text{gingival}}\right)$$

$$\Theta_3 = \arctan\left(\frac{1}{\text{slope}_{\text{gingival}}}\right) - \arctan\left(\frac{1}{\text{slope}_{\text{incisal}}}\right)$$

V. RESULTS

The quantitative results for each of the six brackets included in the study, the distances of the bracket slot at the bottom and the top were measured (Appendix A-F). The results are summarized in the tables below:

Table 1: Distance at the slot bottom (mm)

slot bottom	All	Bracket 1	Bracket 2	Bracket 3	Bracket 4	Bracket 5	Bracket 6
n	180	30	30	30	30	30	30
mean	0.536	0.525	0.543	0.524	0.527	0.527	0.568
SD	0.178	0.004	0.006	0.004	0.013	0.007	0.012
median	0.529	0.527	0.542	0.524	0.527	0.527	0.569
IQR	0.020	0.004	0.006	0.004	0.013	0.007	0.012
normal distr		no	no	yes	yes	yes	yes

Data is not normally distrubuted ($p<0.00001$), medians are significantly different

Table 2: Distance at the slot top (mm)

slot top	All	Bracket 1	Bracket 2	Bracket 3	Bracket 4	Bracket 5	Bracket 6
n	180	30	30	30	30	30	30
mean	0.551	0.554	0.552	0.534	0.557	0.543	0.582
SD	0.019	0.005	0.007	0.004	0.011	0.008	0.022
median	0.547	0.540	0.551	0.533	0.558	0.543	0.579
IQR	0.021	0.004	0.007	0.005	0.013	0.010	0.015
normal distr		no	yes	yes	yes	yes	no

Data is not normally distributed ($p<0.00001$), medians are significantly different

Figure 11: Box plots of the distance at the slot bottom

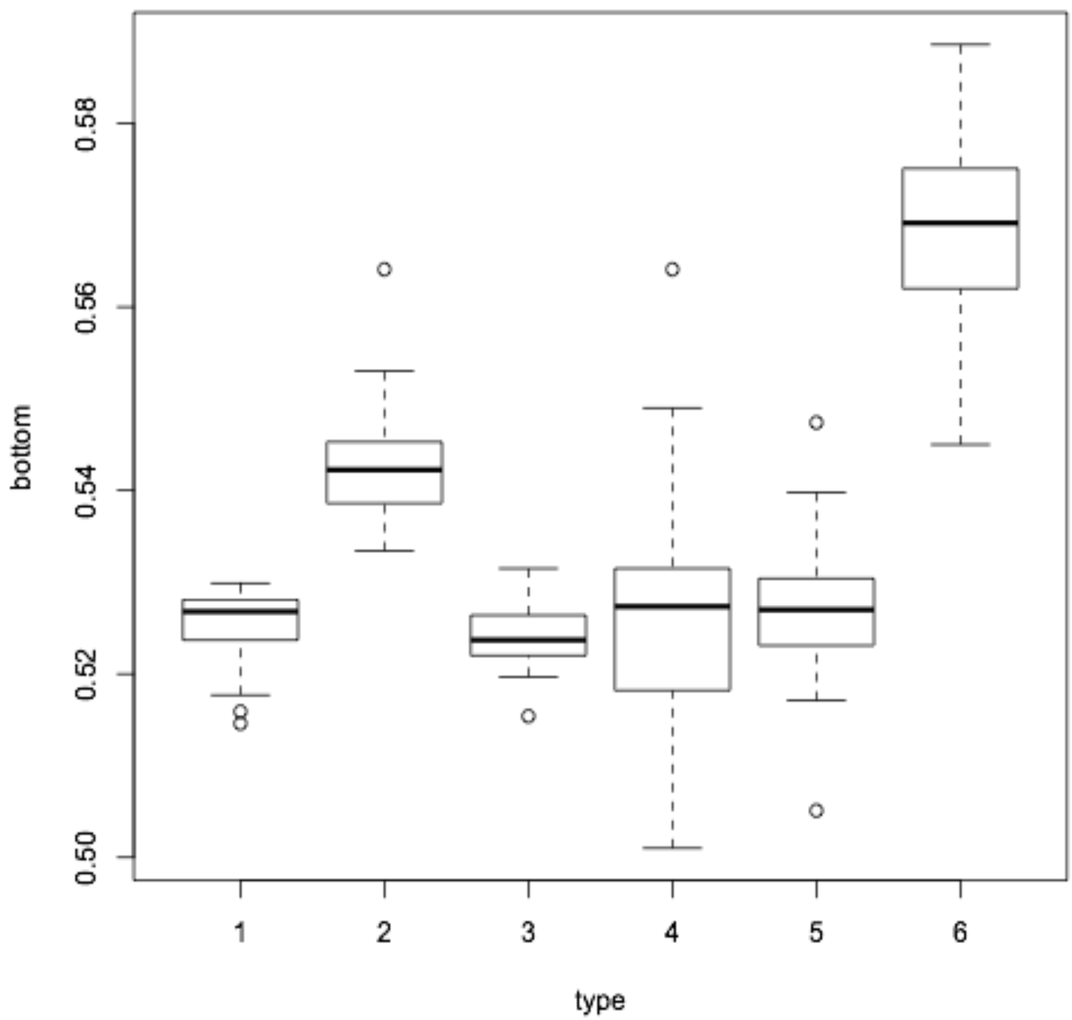
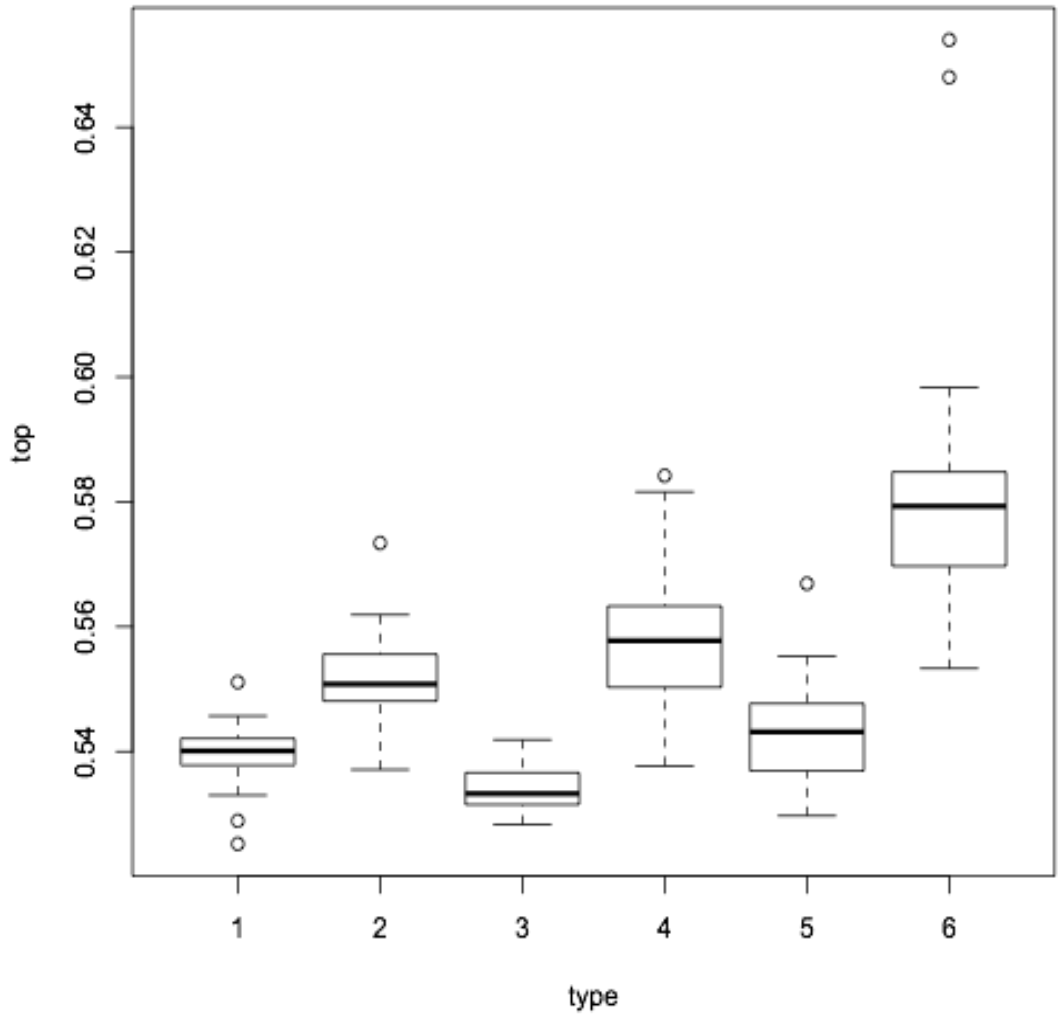


Figure 12: Box plots of the distance at the slot top



For each of the six brackets included in the study, the angles between the walls of the bracket at intersection of the incisal and bottom of the slot and the gingival and bottom of the slot were calculated (Appendix A-F). The results are summarized in the tables below:

Table 3: Angle between the walls of the incisal and bottom of bracket slot

Θ_1	All	Bracket 1	Bracket 2	Bracket 3	Bracket 4	Bracket 5	Bracket 6
n	180	30	30	30	30	30	30
mean	91.02	91.22	90.55	90.81	92.38	90.79	90.35
SD	1.67	0.78	0.73	0.89	2.50	1.17	2.20
median	90.94	91.33	90.60	90.85	92.83	90.64	90.33
IQR	1.63	0.78	1.02	1.12	4.06	1.23	2.54
normal distr		no	yes	yes	yes	yes	yes

Data is not normally distributed, medians are significantly different

Table 4: Angle between the walls of the gingival and bottom of bracket slot

Θ_2	All	Bracket 1	Bracket 2	Bracket 3	Bracket 4	Bracket 5	Bracket 6
n	180	30	30	30	30	30	30
mean	90.85	90.30	90.63	90.45	91.59	90.97	91.15
SD	1.41	0.53	0.56	0.76	2.35	1.17	1.72
median	90.59	90.29	90.48	90.43	91.63	90.89	91.05
IQR	1.26	0.67	0.67	0.60	2.54	1.23	2.41
normal distr		yes	yes	no	yes	no	yes

Data is not normally distributed, medians are significantly different

Figure 13: Box plots of the angle between incisal and bottom of bracket slot

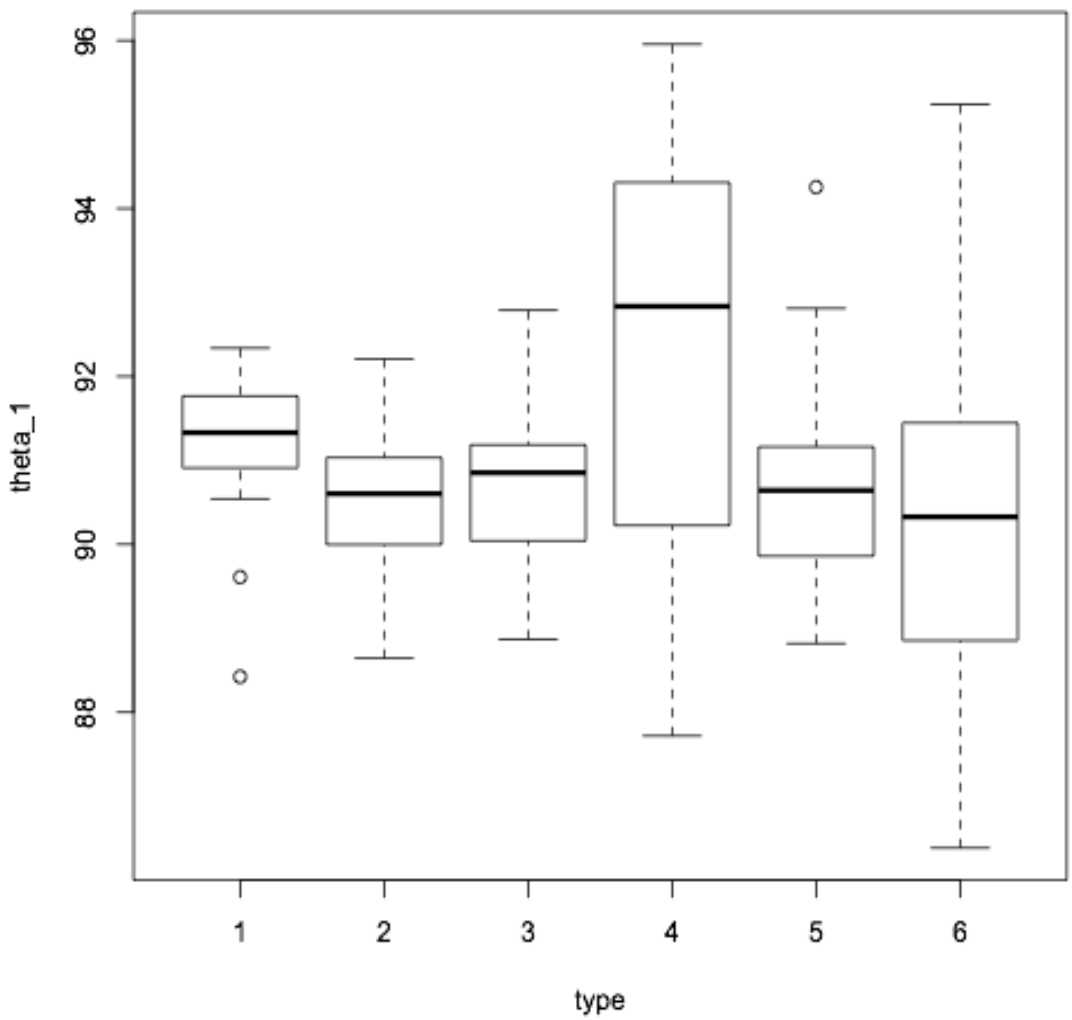
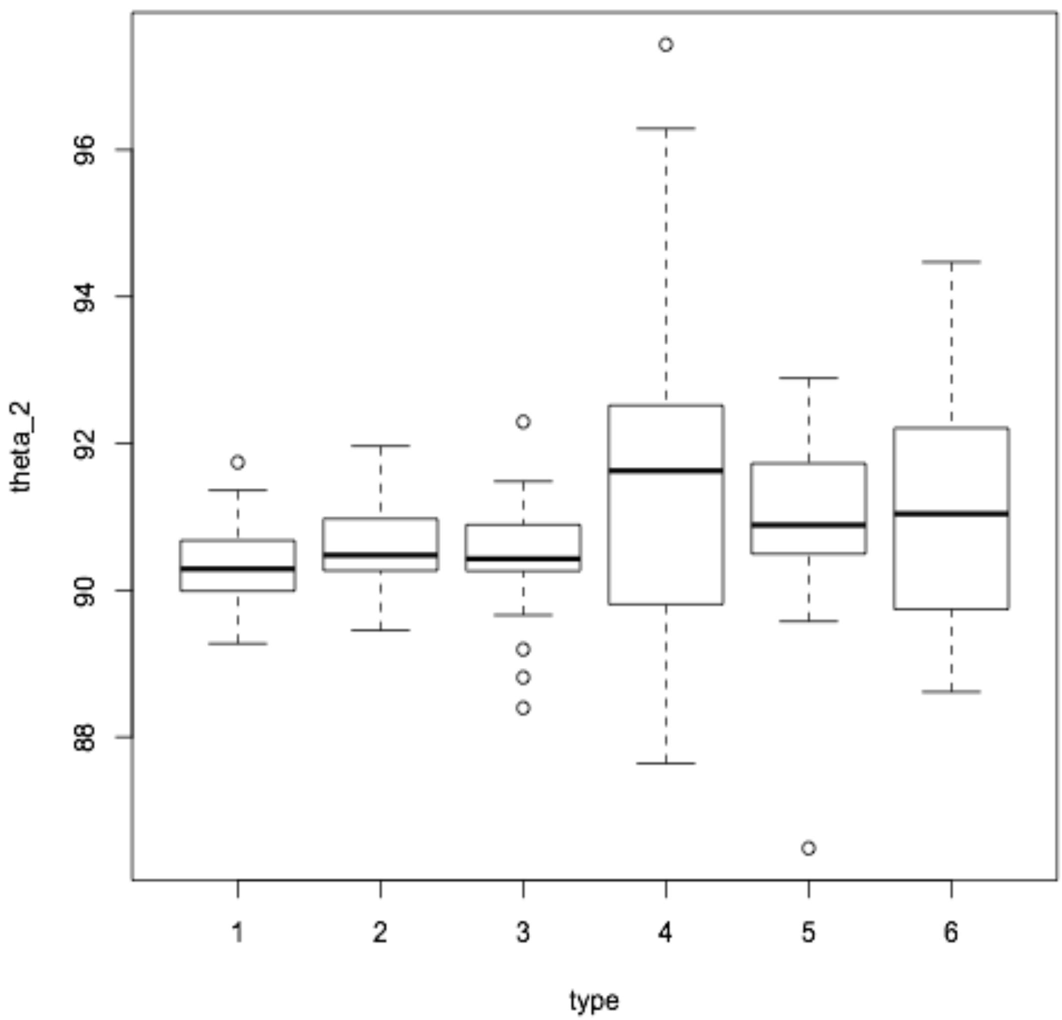


Figure 14: Box plots of the angle between gingival and bottom of bracket slot



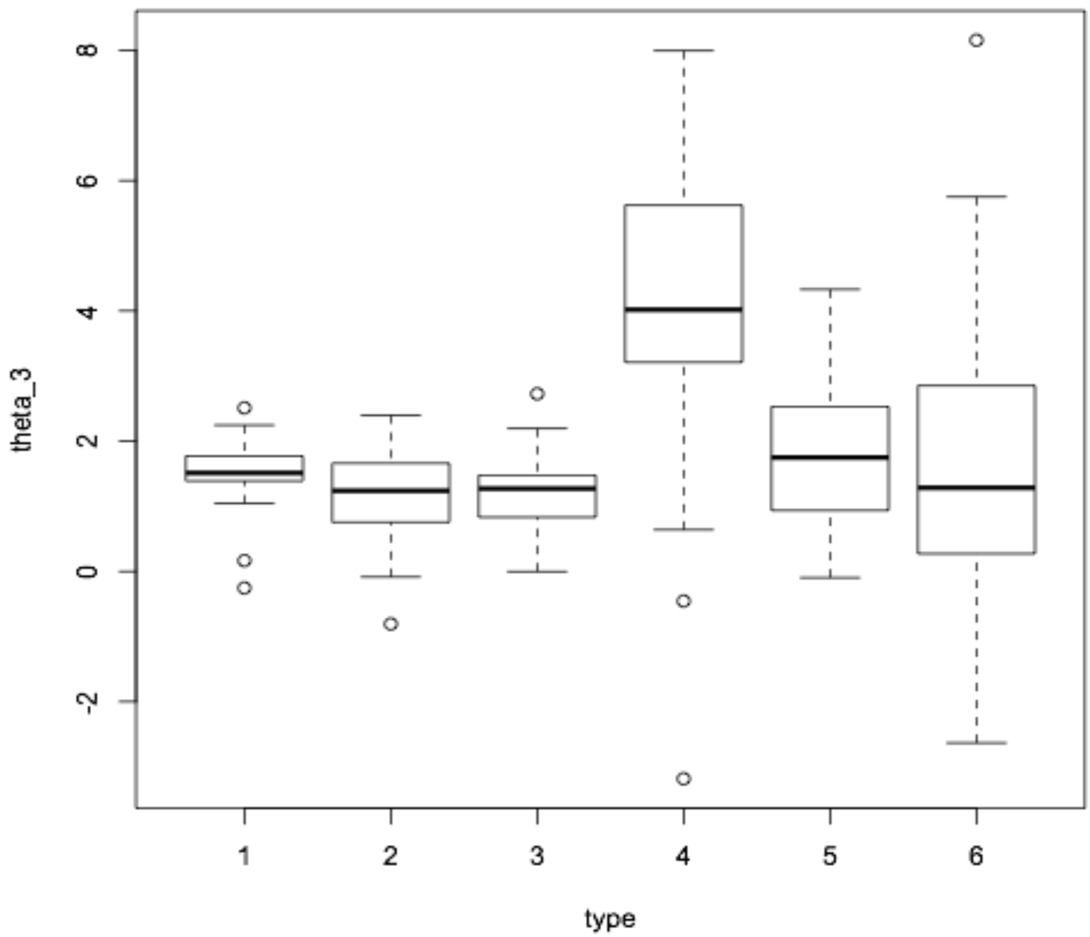
For each of the 6 brackets included in the study, the angle of taper between the incisal and gingival walls of the bracket slot were calculated (Appendix A-F). The results are summarized in the tables below:

Table 5: Angle of taper between the incisal and gingival walls of the bracket slot

$\boldsymbol{\Theta_3}$	All	Bracket 1	Bracket 2	Bracket 3	Bracket 4	Bracket 5	Bracket 6
n	180	30	30	30	30	30	30
mean	1.86	1.50	1.18	1.26	3.96	1.76	1.50
SD	1.76	0.53	0.72	0.56	2.31	1.09	2.40
median	1.53	1.51	1.24	1.27	4.02	1.75	1.28
IQR	1.47	0.37	0.88	0.57	2.38	1.54	2.55
normal distr		no	yes	yes	yes	yes	yes

Data is not normally distributed, medians are significantly different

Figure 15: Box plots of the angle of taper of the bracket slot



For each of the six brackets included in the study, the coefficient of determination (R^2) for the gingival, incisal, and bottom wall of the bracket slot were calculated (Appendix A-F). The results are summarized in the tables below:

Table 6: Coefficient of determination (R^2) of gingival wall

R^2 gingival	All	Bracket 1	Bracket 2	Bracket 3	Bracket 4	Bracket 5	Bracket 6
n	180	30	30	30	30	30	30
mean	0.996	0.999	0.998	0.999	0.987	0.995	0.995
SD	0.011	0.001	0.002	0.002	0.024	0.004	0.005
median	0.998	0.999	0.999	0.9996	0.994	0.997	0.996
IQR	0.004	0.002	0.002	0.001	0.009	0.004	0.006
normal distr		no	no	no	no	no	no

Data is not normally distributed, medians are significantly different

Table 7: Coefficient of determination (R^2) of incisal wall

R^2 incisal	All	Bracket 1	Bracket 2	Bracket 3	Bracket 4	Bracket 5	Bracket 6
n	180	30	30	30	30	30	30
mean	0.987	0.985	0.984	0.997	0.977	0.989	0.989
SD	0.022	0.030	0.019	0.003	0.031	0.019	0.016
median	0.995	0.992	0.988	0.998	0.984	0.996	0.995
IQR	0.013	0.008	0.019	0.004	0.025	0.008	0.010
normal distr		no	no	no	no	no	no

Data is not normally distributed, medians are significantly different

Table 8: Coefficient of determination (R^2) of bottom wall

R^2 bottom	All	Bracket 1	Bracket 2	Bracket 3	Bracket 4	Bracket 5	Bracket 6
n	180	30	30	30	30	30	30
mean	0.984	0.995	0.987	0.989	0.963	0.984	0.989
SD	0.023	0.005	0.013	0.011	0.025	0.041	0.010
median	0.993	0.997	0.993	0.993	0.969	0.993	0.993
IQR	0.014	0.005	0.014	0.013	0.031	0.006	0.009
normal distr		no	no	no	no	no	no

Data is not normally distributed, medians are significantly different

Figure 16: Box plots of the coefficient of determination (R^2) of the gingival wall

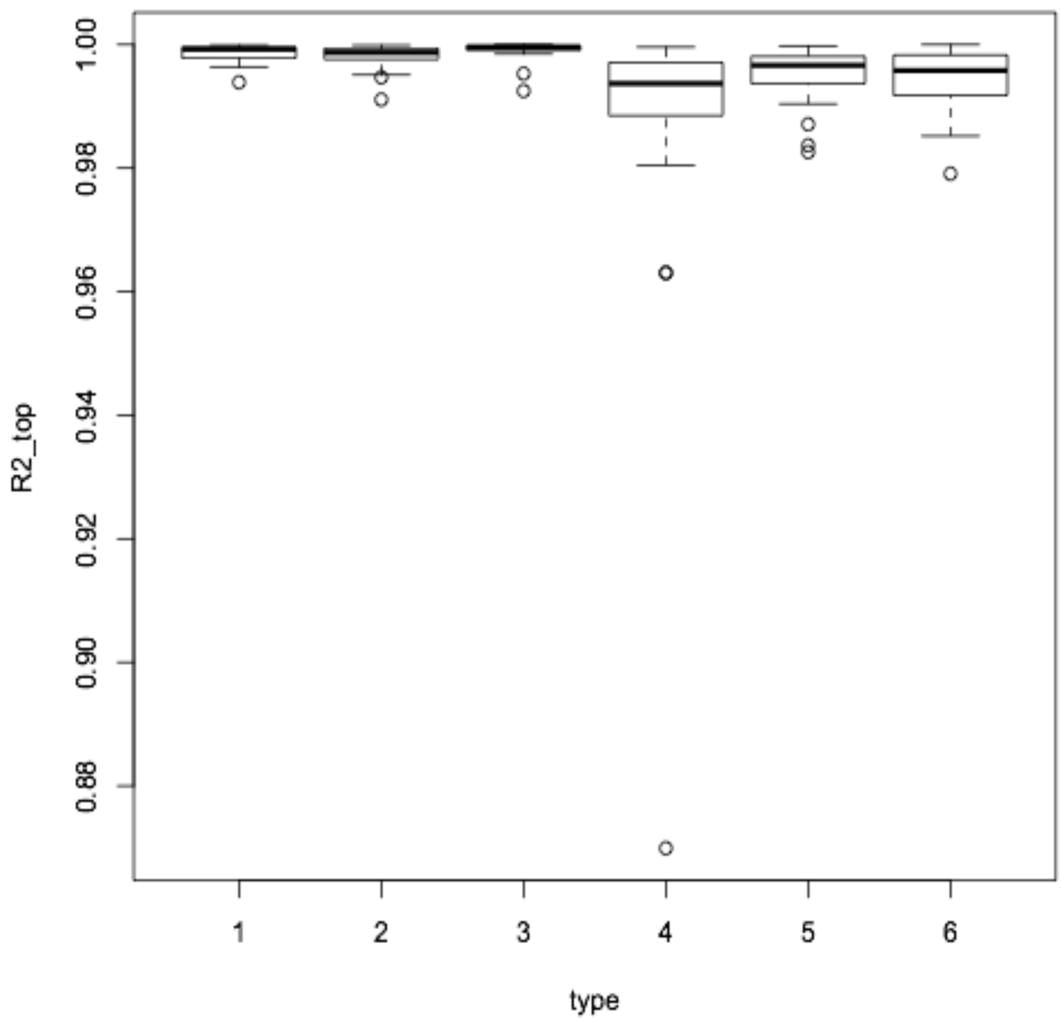


Figure 17: Box plots of the coefficient of determination (R^2) of incisal wall

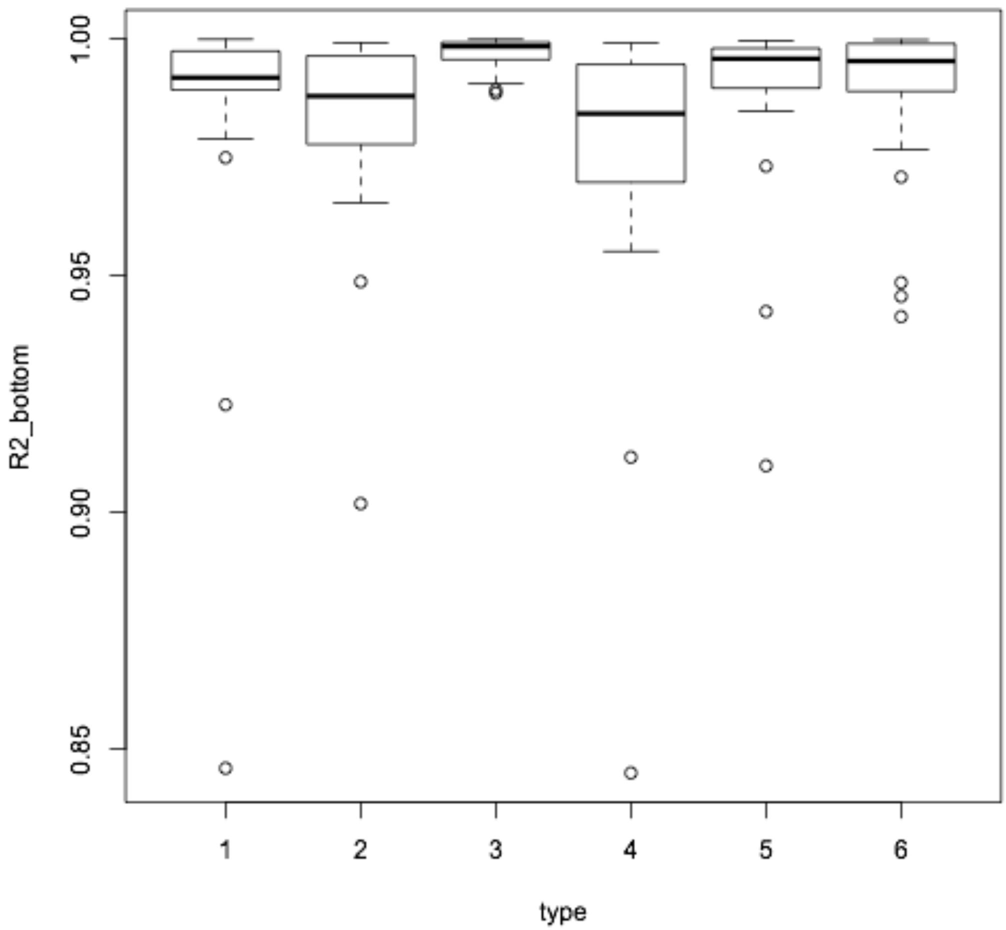
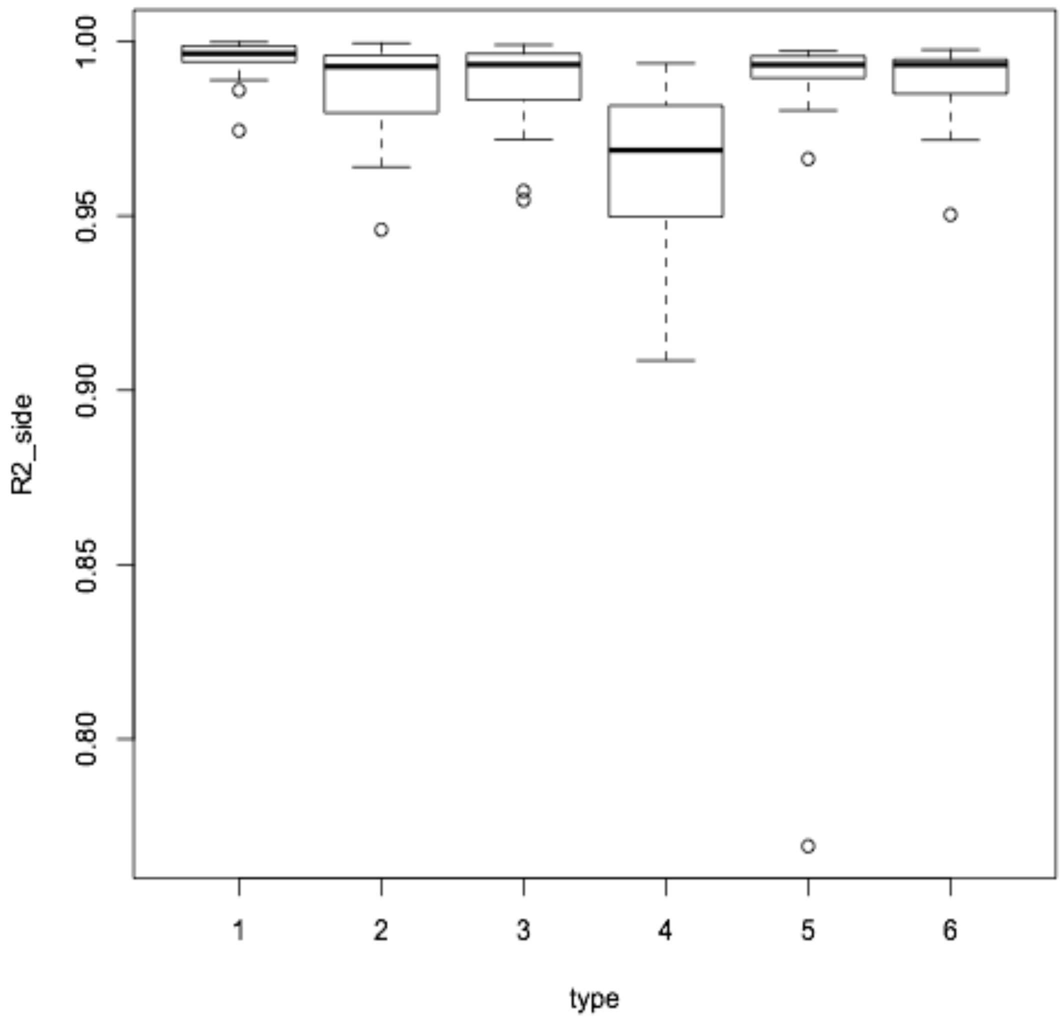


Figure 18: Box plots of the coefficient of determination (R^2) of bottom wall



For each of the eight values calculated for each bracket in the study above, the Shapiro-Wilk test was used to look for normal distribution of the data (Tables 1-8). Since the data did not show a normal distribution the Kruskal-Wallis test was used to determine if there were significant differences in the medians of the data (Tables 1-8). Since there were significant differences, a post-hoc test was necessary, and the Wilcoxon Signed Rank Test was used to determine where those differences occurred with a level of significance set at α = 0.05 (Appendix G). The results are summarized in the tables below:

Table 9: Medians (interquartile range)

	Bracket 1	Bracket 2	Bracket 3	Bracket 4	Bracket 5	Bracket 6
Slot Bottom (mm)	0.527 (0.004)^{a}	0.542 (0.006)^{b}	0.524 (0.004)^{a}	0.527 (0.013)^{a}	0.527 (0.007)^{a}	0.569 (0.012)^{c}
Slot Top (mm)	0.540 (0.004)^{a}	0.551 (0.007)^{b}	0.533 (0.005)^{c}	0.558 (0.013)^{d}	0.543 (0.010)^{e}	0.579 (0.015)^{f}
Θ_1 (degrees)	91.33 (0.78)^{a}	90.60 (1.02)^{b}	90.85 (1.12)^{b}	92.83 (2.50)^{c}	90.64 (1.23)^{b}	90.33 (2.54)^{b}
Θ_2 (degrees)	90.29 (0.67)^{a}	90.48 (0.67)^{b,c}	90.43 (0.60)^{a,b,d}	91.63 (2.54)^{c,e}	90.89 (1.23)^{d,e}	91.05 (2.41)^{b,c,d,e}
Θ_3 (degrees)	1.51 (0.37)^{a}	1.24 (0.88)^{b}	1.27 (0.57)^{b}	4.02 (2.38)^{c}	1.75 (1.54)^{a}	1.28 (2.55)^{a,b}
R^2 incisal	0.992 (0.008)^{a,b}	0.988 (0.019)^{b,c}	0.998 (0.004)^{d}	0.984 (0.025)^{c}	0.996 (0.008)^{a}	0.995 (0.010)^{a}
R^2 gingival	0.999 (0.001)^{a}	0.999 (0.002)^{a}	0.9996 (0.002)^{b}	0.994 (0.009)^{c}	0.997 (0.004)^{c}	0.996 (0.006)^{c}
R^2 bottom	0.997 (0.005)^{a}	0.993 (0.014)^{b}	0.993 (0.013)^{b}	0.969 (0.031)^{c}	0.993 (0.006)^{b}	0.993 (0.009)^{b}

Means with the same letter are not significantly different from each other ($p<0.05$)

VI. DISCUSSION

Images of each bracket are shown in Figures 1-6. Avex Suite (Opal) brackets had well pronounced walls and corners with only occasional burr marks. They also had a deeper slot than most of the other brackets even though the slot depth was not measured in this study. Victory Series (3M) brackets had rounder corners and a more uniform finish. Mini Master (American) brackets also had similar corners as the Avex Suite but with a shallower slot and occasional long surface marks. Precision Series (Elite Ortho) had a shallower slot with more rounded corners than the Victory Series brackets and a pockmarked appearance. The Marquis (Orthotechnology) brackets had a raised ridge surrounding the slot with square corners and also had a pockmarked appearance. The Stratus (Fairfield) bracket had rounded corners and a smooth finish with a number of crater defects. Overall, the brackets were grossly consistent; however, the Precision Series was notable in having the most discernable defects.

Median measurements of all the six bracket types are listed in Table 9, Section VI. Compared to the nominal slot size of 0.022” (0.559 mm) all of the brackets except for the Stratus bracket had a bottom slot that was undersized. The Avex, Mini Master, Precision, and Marquis brackets were all undersized by 5.7% and the differences amongst them were not significant. The Victory series bracket was undersized by 3.0%. The Stratus Series bracket was oversized by 1.8%. The differences were significant.

The differences among the median measurements of all six bracket slot tops were significant. The Avex Suite, Victory Series, Mini Master Series, Precision Series, and Marquis were undersized by 3.4%, 1.4%, 4.7%, 0.2%, and 2.9%, respectively. The Stratus bracket was oversized by 3.4%.

Little variability in the brackets was exhibited by the small Interquartile Ranges from 0.00016-0.00059 inches (0.004-0.015 mm) and Standard Deviations from 0.00016-0.00087 inches (0.004-0.022 mm). The Avex Suite, Victory Series, and Mini Master Series all showed the least amount of variability in dimension. The Precision, Marquis, and Stratus brackets showed twice the variability on size as that of the previously mentioned brackets. The clinical significance of this variability is debatable. Often manufacturing tolerances are reported as being ±2 standard deviations since 95% of all data is within 2 standard deviations of the average (15). Based on the work of Major et al. and Meling et al., the difference in the torque expression among the six brackets would not be clinically significant based on the nominal measurement of 0.022" (0.559 mm) (15, 19).

All of the walls of the six brackets displayed high levels of linearity. The only bracket that did not have a Coefficient of Determination (R^2) of 0.993 or better was the Precision bracket bottom wall, which had an R^2 of 0.969 and tended to be more curved. All of the measurements were within one standard deviation of an R^2 of 1.000 on all three walls. As noted in Major et al., taking only five equally spaced points on each wall is not a full profile analysis (15). It is possible that in this study some of the irregularity could have been lost by selecting points that do not correspond to areas of difference. Furthermore, the differences in linearity must be severe to be able to draw conclusions from an R^2 that is generated from only five points.

The Victory Series and Mini Master brackets were the most rectangular and showed no significant differences in the measurements of the angles between the incisal-bottom walls and gingival-bottom walls. This rectangularity resulted in a degree of divergence (Θ_3) between 1.24-1.27° and in the small difference between the top and bottom distances (0.019 mm). The Apex Suite bracket, although, also rectangular had a small angle of divergence (Θ_3 = 1.51°) that was significantly greater than the previous two. The Stratus bracket , although also displaying these qualities, showed more variation (Θ_3 = 1.28°, IQR= 2.55°). The Precision and Marquis bracket showed much less rectangularity than all the others with a greater degree of divergence (Θ_3 = 4.02°, Θ_3 = 1.75°) and greater variability.

This study did not investigate the radius of the round corners of the brackets, and the points for analysis were not selected in the rounds as in similar studies (15). Since the roundness of the bracket slot corners was not measured, an estimate of the way in which the roundness affected the assumed normal trapezoid shape of the slot could not be determined. Furthermore, the slot depth was not measured, and, with taper, the longer the slot depth, the larger the difference between the top and the bottom slot measurements. This study also only measured the mesial of the brackets, and it is possible that a difference between the mesial and distal would occur.

The six brackets in this study were aligned visually under a microscope and then fitted into a matrix that reproduced the angle for next bracket to be photographed. If the angle of any brackets was off, it could affect the measurements and increase the variability. A potential resolution could be to scan the brackets three-dimensionally and analyze them volumetrically. In addition, including more points along the bracket slot walls could measure maximum variations and identify all repeatable imperfections in the brackets.

The International Standard for Dentistry—Brackets and Tubes for Use in Orthodontics was published recently. However, no guidelines stated for manufacturing tolerances-only that the range of each dimension shall be stated on the label (6). The ISO states that the slot shall be measured to the nearest 0.01 mm with an instrument accuracy of 0.005 mm. In addition, the ISO states that the angles shall be recorded to the nearest 1° with an instrument accuracy of 0.5°. Given the ISO lack of specificity, this study agrees with other studies that the tolerances should be stated and published to a universal standard (15).

VII. CONCLUSION

The Victory Series (3M) bracket showed the overall best dimensional accuracy with a slot bottom of 0.542 mm and slot top of 0.551 mm, which was 3.0% and 1.4% smaller than the nominal size 0f 0.559 mm, respectively. The bracket also showed excellent rectangularity with Θ_1 and Θ_2 wall angles of 90.60° and 90.48°, respectively. In addition, the taper or degree of the divergence, Θ_3, was the smallest at 1.24°. Finally, the walls showed excellent linearity (R^2).

The Avex Suite (Opal) and the Mini Master Series (American) brackets also showed excellent dimensional accuracy but were more undersized than the Victory Series brackets at 5.7% at the bottom and 3.4% and 4.7% at the top. They both also showed good rectangularity, excellent linearity, and very little variability.

The Stratus (Fairfield) bracket showed excellent dimensional accuracy with a slot bottom of 0.569 mm and 0.579 mm, which was 1.8% and 3.4% larger than the nominal size, respectively. The bracket also showed a good degree of taper (Θ_3) of 1.28° and excellent linearity. However, it showed a high amount of variability.

The Precision (Elite Ortho) and Marquis (Orthotechnology) brackets showed good dimensional accuracy with a slot bottom of 0.527 mm (5.7%) and a slot top of 0.558 (0.2%) and 0.579 mm (2.9%), respectively. These two brackets showed decent linearity with the exception of the bottom of the Precision bracket (R^2= 0.969). Furthermore, the Marquis bracket had the worst degree of taper (Θ_3) of any bracket at 4.02°.

Overall, the brackets were consistent in dimensional accuracy. However, a definite distinction in the dimensional accuracy of the Avex Suite, Victory Series, and Mini Master brackets was exhibited when compared with the rest of the brackets. These brackets were manufactured with Computer Numerically Controlled (CNC) milling. Interestingly, the Precision brackets also were CNC milled but showed poor dimensional accuracy. The Stratus brackets were Metal Injection Molded (MIM) and had good accuracy but increased variability. The Marquis brackets, which were cast, showed less dimensional accuracy and more variability than the other brackets. In conclusion, CNC milling has not been proven to produce brackets with greater dimensional accuracy, however, all the brackets with the best dimensional accuracy were CNC milled. The clinical significance of this variability is unclear and further studies are needed including clinical trials.

VIII. APPENDICES

Appendix A: Raw Data—Bracket 1 (Avex Suite, Opal)

Sample	Bottom (mm)	Top (mm)	Θ_1	Θ_2	Θ_3	R^2 Incisal	R^2 Gingival	R^2 Bottom
1	0.529	0.542	91.138	90.258	1.396	0.997	0.999	0.999
2	0.525	0.546	91.207	90.859	1.465	1.000	0.997	1.000
3	0.527	0.541	90.910	90.615	1.525	0.999	0.992	0.999
4	0.524	0.533	90.543	90.729	1.272	0.999	0.998	0.996
5	0.528	0.543	91.828	89.669	1.498	1.000	0.995	0.999
6	0.528	0.542	90.739	90.803	1.542	0.994	1.000	0.999
7	0.525	0.542	91.061	90.678	1.739	0.999	0.997	0.997
8	0.528	0.525	89.609	90.136	-0.255	1.000	0.989	0.998
9	0.529	0.541	91.536	89.956	1.492	0.998	0.991	0.974
10	0.524	0.538	91.475	90.132	1.607	0.999	0.990	0.998
11	0.527	0.542	92.336	89.273	1.610	0.997	0.992	0.993
12	0.525	0.539	90.876	90.512	1.388	1.000	0.991	0.997
13	0.530	0.545	91.348	90.117	1.465	0.996	0.998	0.995
14	0.515	0.537	90.840	91.359	2.198	0.999	0.984	0.996
15	0.524	0.539	91.415	90.047	1.462	0.997	0.999	0.999
16	0.528	0.542	91.006	90.337	1.343	0.999	0.987	0.999
17	0.528	0.544	91.450	90.322	1.772	0.999	0.999	0.997
18	0.529	0.538	90.653	90.390	1.044	1.000	0.994	0.999
19	0.527	0.551	91.765	90.745	2.510	0.999	0.997	0.996
20	0.528	0.540	90.980	90.363	1.343	0.999	0.982	0.995
21	0.528	0.545	91.531	90.043	1.574	1.000	0.990	0.986
22	0.522	0.539	91.844	89.754	1.598	1.000	0.993	0.997
23	0.518	0.536	91.312	90.709	2.021	0.998	0.990	0.993
24	0.521	0.538	92.041	89.774	1.815	0.998	0.997	0.993
25	0.528	0.540	91.233	89.990	1.223	0.998	0.996	0.996
26	0.516	0.537	92.258	89.988	2.246	0.999	0.979	0.996
27	0.524	0.540	91.481	90.334	1.815	0.997	0.990	0.989
28	0.522	0.540	91.820	89.997	1.817	0.998	0.846	0.990
29	0.527	0.529	88.424	91.742	0.165	1.000	0.975	0.994
30	0.521	0.536	92.066	89.359	1.424	1.000	0.923	0.999

Appendix B: Raw data—Bracket 2 (Victory Series, 3M)

Sample	Bottom (mm)	Top (mm)	Θ_1	Θ_2	Θ_3	R^2 Incisal	R^2 Gingival	R^2 Bottom
1	0.538	0.551	91.053	90.472	1.525	1.000	0.997	0.994
2	0.542	0.549	90.602	90.281	0.883	0.995	0.984	0.978
3	0.537	0.552	91.616	90.233	1.850	0.999	0.981	0.966
4	0.547	0.556	90.976	90.266	1.242	0.998	0.999	0.978
5	0.544	0.552	90.597	90.482	1.078	0.998	0.983	0.980
6	0.546	0.557	90.964	90.455	1.419	0.999	0.949	0.988
7	0.542	0.545	89.962	90.398	0.360	0.991	0.995	0.965
8	0.545	0.561	91.328	90.841	2.169	1.000	0.997	0.993
9	0.564	0.573	89.527	91.707	1.234	0.998	0.975	0.989
10	0.533	0.546	90.995	90.762	1.757	0.999	0.974	0.946
11	0.535	0.548	92.211	89.450	1.660	0.995	0.902	0.964
12	0.550	0.557	90.638	90.233	0.871	0.999	0.965	0.967
13	0.539	0.556	91.508	90.824	2.332	1.000	0.998	0.996
14	0.543	0.550	89.997	90.974	0.970	0.997	0.985	0.997
15	0.542	0.545	90.190	90.361	0.551	0.998	0.974	0.996
16	0.549	0.548	89.674	90.239	-0.086	0.997	0.990	0.996
17	0.538	0.552	91.142	90.754	1.895	0.999	0.978	0.999
18	0.542	0.548	89.585	91.120	0.706	0.998	0.997	0.992
19	0.539	0.550	90.408	91.106	1.513	0.999	0.992	0.999
20	0.547	0.561	90.379	91.522	1.901	1.000	0.996	0.999
21	0.540	0.550	91.034	90.411	1.444	0.998	0.997	0.998
22	0.544	0.562	90.435	91.962	2.398	0.999	0.996	0.994
23	0.542	0.552	89.968	91.355	1.324	0.999	0.976	0.994
24	0.542	0.548	90.614	90.298	0.912	0.999	0.986	0.990
25	0.544	0.550	90.009	90.745	0.755	0.999	0.993	0.990
26	0.539	0.551	90.604	91.057	1.661	1.000	0.984	0.993
27	0.537	0.544	90.774	89.960	0.735	0.998	0.996	0.993
28	0.553	0.554	89.983	90.169	0.152	0.999	0.978	0.997
29	0.543	0.537	88.642	90.551	-0.808	0.998	0.991	0.994
30	0.540	0.547	91.203	89.774	0.977	0.999	0.998	0.988

Appendix C: Raw Data—Bracket 3 (Mini Master, American)

Sample	Bottom (mm)	Top (mm)	Θ_1	Θ_2	Θ_3	R^2 Incisal	R^2 Gingival	R^2 Bottom
1	0.521	0.534	90.890	90.891	1.782	1.000	0.996	0.995
2	0.520	0.537	91.618	90.575	2.192	0.993	0.990	0.990
3	0.527	0.533	92.002	88.811	0.813	0.999	0.995	0.954
4	0.520	0.532	90.740	90.713	1.453	0.999	0.997	0.982
5	0.531	0.531	90.041	89.957	-0.002	1.000	0.996	0.994
6	0.526	0.531	90.190	90.441	0.631	1.000	0.998	0.999
7	0.523	0.533	92.786	88.395	1.181	1.000	0.996	0.995
8	0.523	0.534	88.870	92.294	1.164	1.000	0.991	0.980
9	0.523	0.536	92.054	89.661	1.715	0.999	0.999	0.998
10	0.521	0.532	91.145	90.306	1.451	0.999	0.991	0.957
11	0.522	0.532	90.580	90.571	1.152	0.999	0.999	0.995
12	0.528	0.531	89.960	90.365	0.324	1.000	0.989	0.972
13	0.526	0.533	90.017	90.814	0.832	0.998	0.988	0.980
14	0.532	0.542	90.091	91.099	1.190	1.000	0.997	0.983
15	0.523	0.530	89.847	90.983	0.829	0.999	0.993	0.985
16	0.524	0.536	90.934	90.543	1.477	1.000	0.998	0.997
17	0.515	0.537	92.312	90.415	2.727	1.000	0.999	0.981
18	0.520	0.531	91.185	90.261	1.446	0.999	0.999	0.995
19	0.524	0.528	90.430	90.115	0.545	0.999	0.999	0.993
20	0.522	0.537	91.588	90.300	1.888	1.000	0.999	0.990
21	0.531	0.542	90.966	90.257	1.223	1.000	1.000	0.991
22	0.522	0.532	90.815	90.609	1.425	0.999	1.000	0.996
23	0.520	0.532	91.154	90.405	1.559	0.999	0.999	0.997
24	0.525	0.530	89.605	90.908	0.513	1.000	0.999	0.997
25	0.524	0.533	92.015	89.193	1.208	1.000	1.000	0.986
26	0.526	0.538	89.928	91.482	1.410	1.000	1.000	0.998
27	0.527	0.539	90.933	90.387	1.320	1.000	0.998	0.990
28	0.526	0.541	90.511	91.221	1.732	0.995	1.000	0.998
29	0.524	0.534	91.091	90.301	1.392	1.000	0.998	0.994
30	0.525	0.534	89.964	91.136	1.100	0.999	0.999	0.998

Appendix D: Raw Data—Bracket 4 (Precision, Elite Ortho)

Sample	Bottom (mm)	Top (mm)	Θ_1	Θ_2	Θ_3	R^2 Incisal	R^2 Gingival	R^2 Bottom
1	0.545	0.551	88.613	92.025	0.639	0.996	0.999	0.987
2	0.549	0.545	90.294	89.250	-0.455	0.870	0.912	0.950
3	0.509	0.553	95.954	89.996	5.950	0.987	0.955	0.945
4	0.531	0.558	91.264	91.965	3.229	0.990	0.966	0.912
5	0.518	0.546	92.405	91.597	4.002	0.984	0.983	0.956
6	0.532	0.556	88.357	94.854	3.211	1.000	0.993	0.965
7	0.564	0.538	89.178	87.638	-3.184	0.996	0.970	0.988
8	0.526	0.551	94.309	89.248	3.557	0.963	0.845	0.956
9	0.529	0.558	87.719	96.288	4.007	0.999	0.975	0.982
10	0.531	0.572	93.564	91.657	5.220	0.997	0.969	0.966
11	0.528	0.550	91.858	90.931	2.789	0.998	0.984	0.936
12	0.544	0.561	89.586	92.568	2.154	0.997	0.996	0.987
13	0.521	0.545	94.871	88.508	3.379	0.980	0.997	0.979
14	0.514	0.563	88.588	97.435	6.023	0.989	0.997	0.909
15	0.527	0.566	93.008	91.851	4.859	0.993	0.995	0.981
16	0.520	0.567	93.785	91.838	5.623	0.990	0.982	0.975
17	0.531	0.561	95.151	88.878	4.029	0.990	0.999	0.987
18	0.515	0.558	95.423	90.090	5.513	0.995	0.957	0.974
19	0.522	0.562	95.026	89.807	4.833	0.994	0.984	0.986
20	0.518	0.549	93.511	90.340	3.851	0.992	0.993	0.969
21	0.531	0.565	93.691	90.806	4.497	0.963	0.967	0.912
22	0.530	0.553	90.226	92.518	2.744	0.998	0.997	0.990
23	0.512	0.552	95.924	89.799	5.723	0.994	0.996	0.969
24	0.536	0.544	89.266	91.691	0.957	0.989	0.970	0.941
25	0.517	0.584	92.660	95.333	7.993	0.997	0.992	0.954
26	0.530	0.559	94.752	89.174	3.925	0.998	0.978	0.955
27	0.534	0.582	92.466	93.185	5.651	0.999	0.990	0.969
28	0.523	0.559	93.130	91.436	4.567	0.997	0.988	0.994
29	0.501	0.549	94.299	92.034	6.333	0.988	0.981	0.926
30	0.512	0.566	92.458	94.849	7.307	0.998	0.995	0.978

Appendix E: Raw Data—Bracket 5 (Marquis, Orthotechnology)

Sample	Bottom (mm)	Top (mm)	Θ_1	Θ_2	Θ_3	R^2 Incisal	R^2 Gingival	R^2 Bottom
1	0.530	0.533	90.709	89.574	0.283	0.987	0.942	0.997
2	0.540	0.555	91.271	90.496	1.767	0.983	0.990	0.997
3	0.539	0.544	88.820	91.740	0.560	0.990	0.973	0.966
4	0.522	0.548	90.887	92.142	3.029	0.997	0.985	0.994
5	0.524	0.548	90.134	92.266	2.401	0.996	0.910	0.984
6	0.539	0.541	90.496	89.740	0.236	0.994	0.992	0.990
7	0.524	0.539	90.805	90.796	1.601	0.998	0.985	0.980
8	0.518	0.543	92.755	90.194	2.949	0.998	0.996	0.990
9	0.526	0.548	90.273	92.140	2.413	0.997	0.997	0.997
10	0.534	0.543	89.861	91.185	1.046	0.998	0.997	0.994
11	0.538	0.537	89.192	90.712	-0.096	0.994	0.994	0.984
12	0.532	0.551	91.150	91.024	2.174	0.996	0.989	0.993
13	0.530	0.543	89.668	91.671	1.339	0.996	0.997	0.988
14	0.517	0.534	89.658	92.315	1.974	0.997	0.999	0.993
15	0.526	0.537	90.422	90.727	1.148	0.991	0.986	0.992
16	0.519	0.541	91.953	90.647	2.600	0.998	1.000	0.990
17	0.528	0.567	92.373	91.956	4.329	0.998	1.000	0.997
18	0.523	0.547	91.031	91.717	2.749	0.998	0.998	0.997
19	0.528	0.530	89.692	90.505	0.197	0.997	0.998	0.994
20	0.519	0.550	90.556	92.887	3.443	1.000	0.998	0.996
21	0.505	0.530	92.809	90.206	3.015	1.000	0.996	0.995
22	0.528	0.530	89.456	90.865	0.322	0.998	0.997	0.994
23	0.547	0.554	94.253	86.484	0.737	0.984	0.990	0.769
24	0.520	0.539	91.253	90.910	2.162	0.997	0.998	0.996
25	0.528	0.543	91.146	90.495	1.641	0.998	0.991	0.986
26	0.526	0.542	91.111	90.618	1.729	0.993	0.997	0.989
27	0.525	0.543	90.481	91.527	2.008	0.996	0.996	0.993
28	0.530	0.545	89.834	91.728	1.562	0.992	0.992	0.993
29	0.523	0.547	91.161	91.370	2.531	0.997	0.992	0.994
30	0.529	0.537	90.575	90.361	0.936	0.998	0.999	0.996

Appendix F: Raw Data—Bracket 6 (Stratus, Fairfield)

Sample	Bottom (mm)	Top (mm)	θ_1	θ_2	θ_3	R^2 Incisal	R^2 Gingival	R^2 Bottom
1	0.569	0.572	91.728	88.613	0.341	0.985	0.985	0.993
2	0.567	0.575	90.999	89.934	0.933	0.996	1.000	0.994
3	0.572	0.584	90.130	91.180	1.310	0.992	0.946	0.994
4	0.571	0.553	86.556	91.355	-2.090	0.999	0.992	0.976
5	0.576	0.648	93.685	94.470	8.154	0.986	0.941	0.995
6	0.576	0.555	86.384	90.983	-2.633	0.998	0.999	0.984
7	0.569	0.583	89.500	92.209	1.709	0.998	0.995	0.988
8	0.545	0.578	95.239	88.721	3.960	0.998	0.948	0.990
9	0.576	0.572	87.593	92.008	-0.399	0.994	0.990	0.994
10	0.581	0.565	88.885	89.237	-1.878	0.999	0.992	0.950
11	0.571	0.575	91.565	88.962	0.527	0.998	0.999	0.997
12	0.576	0.581	90.120	90.440	0.561	0.999	0.999	0.995
13	0.581	0.568	88.855	89.685	-1.460	0.993	1.000	0.997
14	0.548	0.581	94.766	89.106	3.872	0.999	0.997	0.998
15	0.560	0.569	91.270	89.741	1.011	0.992	0.995	0.987
16	0.573	0.566	88.665	90.564	-0.771	0.998	0.999	0.994
17	0.569	0.586	90.654	91.353	2.006	0.999	1.000	0.976
18	0.557	0.571	90.554	91.018	1.572	1.000	1.000	0.997
19	0.589	0.654	93.917	91.833	5.750	0.994	0.998	0.996
20	0.565	0.597	89.693	93.837	3.530	0.996	0.996	0.988
21	0.575	0.598	92.441	90.123	2.564	0.988	0.977	0.988
22	0.546	0.583	89.978	94.164	4.142	0.996	0.985	0.994
23	0.559	0.584	90.703	92.150	2.853	0.998	0.997	0.994
24	0.554	0.585	90.524	93.101	3.625	0.992	0.989	0.996
25	0.569	0.592	88.684	94.119	2.802	0.994	0.971	0.994
26	0.569	0.581	88.915	92.342	1.257	0.990	0.998	0.984
27	0.567	0.570	91.093	89.179	0.272	0.979	0.995	0.972
28	0.571	0.559	87.684	91.063	-1.253	0.994	0.995	0.985
29	0.575	0.586	88.289	92.935	1.223	0.996	0.990	0.989
30	0.562	0.575	91.448	90.109	1.557	0.997	0.996	0.983

Appendix G: Group contrasts

Group Contrasts		method: Wilcoxon rank sum test						
Bottom	p-value		**Θ1**	p-value	comments	**R^2 bottom**	p-value	
2 to 1	3.01E-11	medians are not equivalent	2 to 1	0.0001	medians are not equivalent	2 to 1	0.145	medians are equivalent
3 to 1	0.075	medians are equivalent	3 to 1	0.022	medians are not equivalent	3 to 1	0.0003	medians are not equivalent
4 to 1	0.506	medians are equivalent	4 to 1	0.012	medians are not equivalent	4 to 1	0.036	medians are not equivalent
5 to 1	0.301	medians are equivalent	5 to 1	0.010	medians are not equivalent	5 to 1	0.429	medians are equivalent
6 to 1	3.01E-11	medians are not equivalent	6 to 1	0.009	medians are not equivalent	6 to 1	0.297	medians are equivalent
3 to 2	3.01E-11	medians are not equivalent	3 to 2	0.358	medians are equivalent	3 to 2	0.00001	medians are not equivalent
4 to 2	2.47E-07	medians are not equivalent	4 to 2	0.003	medians are not equivalent	4 to 2	0.404	medians are equivalent
5 to 2	6.21E-09	medians are not equivalent	5 to 2	0.644	medians are equivalent	5 to 2	0.033	medians are not equivalent
6 to 2	2.86E-10	medians are not equivalent	6 to 2	0.485	medians are equivalent	6 to 2	0.044	medians are not equivalent
4 to 3	0.399	medians are equivalent	4 to 3	0.005	medians are not equivalent	4 to 3	0.000001	medians are not equivalent
5 to 3	0.057	medians are equivalent	5 to 3	0.687	medians are equivalent	5 to 3	0.004	medians are not equivalent
6 to 3	3.00E-11	medians are not equivalent	6 to 3	0.192	medians are equivalent	6 to 3	0.030	medians are not equivalent
5 to 4	0.767	medians are equivalent	5 to 4	0.009	medians are not equivalent	5 to 4	0.007	medians are not equivalent
6 to 4	8.95E-11	medians are not equivalent	6 to 4	0.003	medians are not equivalent	6 to 4	0.009	medians are not equivalent
6 to 5	3.67E-11	medians are not equivalent	6 to 5	0.260	medians are equivalent	6 to 5	0.756	medians are equivalent
Top	p-value		**Θ2**	p-value	comments	**R^2 top**	p-value	comments
2 to 1	2.02E-09	medians are not equivalent	2 to 1	0.016	medians are not equivalent	2 to 1	0.239	medians are equivalent
3 to 1	9.14E-06	medians are not equivalent	3 to 1	0.130	medians are equivalent	3 to 1	0.020	medians are not equivalent
4 to 1	1.28E-09	medians are not equivalent	4 to 1	0.019	medians are not equivalent	4 to 1	3.62E-07	medians are not equivalent
5 to 1	0.048	medians are not equivalent	5 to 1	0.0002	medians are not equivalent	5 to 1	1.73E-05	medians are not equivalent
6 to 1	3.01E-11	medians are not equivalent	6 to 1	0.070	medians are not equivalent	6 to 1	0.00001	medians are not equivalent

3 to 2	4.96E-11	medians are not equivalent	3 to 2	0.602	medians are equivalent	3 to 2	0.0004	medians are not equivalent
4 to 2	0.021	medians are not equivalent	4 to 2	0.103	medians are equivalent	4 to 2	4.07E-06	medians are not equivalent
5 to 2	7.20E-06	medians are not equivalent	5 to 2	0.029	medians are not equivalent	5 to 2	0.0002	medians are not equivalent
6 to 2	5.07E-10	medians are not equivalent	6 to 2	0.328	medians are equivalent	6 to 2	0.0001	medians are not equivalent
4 to 3	4.96E-11	medians are not equivalent	4 to 3	0.046	medians are not equivalent	4 to 3	6.89E-09	medians are not equivalent
5 to 3	3.95E-06	medians are not equivalent	5 to 3	0.084	medians are equivalent	5 to 3	7.45E-08	medians are not equivalent
6 to 3	3.01E-11	medians are not equivalent	6 to 3	0.146	medians are equivalent	6 to 3	4.95E-08	medians are not equivalent
5 to 4	4.27E-07	medians are not equivalent	5 to 4	0.523	medians are equivalent	5 to 4	0.082	medians are equivalent
6 to 4	1.11E-07	medians are not equivalent	6 to 4	0.552	medians are equivalent	6 to 4	0.176	medians are equivalent
6 to 5	6.68E-11	medians are not equivalent	6 to 5	0.994	medians are equivalent	6 to 5	0.756	medians are equivalent
			Ө3	p-value	comments	**R^2 side**	p-value	comments
			2 to 1	0.047	medians are not equivalent	2 to 1	0.001	medians are not equivalent
			3 to 1	0.011	medians are not equivalent	3 to 1	0.003	medians are not equivalent
			4 to 1	1.027E-06	medians are not equivalent	4 to 1	3.15E-10	medians are not equivalent
			5 to 1	0.240	medians are equivalent	5 to 1	0.001	medians are not equivalent
			6 to 1	0.520	medians are equivalent	6 to 1	0.0002	medians are not equivalent
			3 to 2	0.912	medians are equivalent	3 to 2	0.641	medians are equivalent
			4 to 2	4.286E-08	medians are not equivalent	4 to 2	3.44E-06	medians are not equivalent
			5 to 2	0.027	medians are not equivalent	5 to 2	0.756	medians are equivalent
			6 to 2	0.676	medians are equivalent	6 to 2	0.923	medians are equivalent
			4 to 3	5.959E-08	medians are not equivalent	4 to 3	5.81E-07	medians are not equivalent
			5 to 3	0.046	medians are not equivalent	5 to 3	0.883	medians are equivalent
			6 to 3	0.786	medians are equivalent	6 to 3	0.525	medians are equivalent
			5 to 4	0.000001	medians are not equivalent	5 to 4	1.02E-07	medians are not equivalent
			6 to 4	0.0001	medians are not equivalent	6 to 4	3.12E-07	medians are not equivalent
			6 to 5	0.432	medians are equivalent	6 to 5	0.652	medians are equivalent

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